Researches on drying the clover through aeration to obtain hay

Ana Zaica[1*], *Ancuța* Nedelcu[1], *Radu* Ciupercă[1], *Alexandru* Zaica[1] and *Alexandra-Liana* Vișan[1]

[1] INMA Bucharest, Romania

Abstract. Harvesting, preparation and conservation of hay is a frequent method for harvesting fodder from grasslands and forage crops, especially from the hill and mountain areas. The greatest losses of nutrients are obtained by traditional drying on the stubble of the hay. These losses are in the case of unfavourable weather even at 50 ... 60%, the drying time increasing to over 6 ... 8 days. This paper presents the results of the experimental researches achieved within a new technology for shortening the time from harvesting the clover to obtaining the hay at storage humidity. A pilot ventilation installation with a monitoring and control system for working processes was used to carry out the research. During the experiments, the parameters of the aeration agent were measured: temperature and humidity, as well as clover mass characteristics: humidity, temperature, drying uniformity.

1 Introduction

The directions for development and profitability of the agro-food production, the increase of the volume and the quality of the agricultural production by diminishing the losses in the zoo-technical sector can only be achieved by upgrading, modernizing the machinery and the technical equipment used for carrying out the basic operations within these technologies. These are possible only by making new types of specialized machinery and equipment with high reliability and low operating costs that ensure the application of technologies for the harvesting and preservation of fodder plants with superior technical and economic parameters.

Of particular importance is the contribution of meadows, consisting of pastures and hayfields, to the production of fodders necessary for the development of the zoo-technical field. Because a feed with a floral composition and complete nutritional value, in turn determines a balanced composition in proteins, vitamins, salts and other substances are the basic feed of the animals.

Fodder plants represent an important part of plant production and are subordinated to general principles and methods of agro-technical. However, they have their own biological, ecological and technical particularities, which distinguish them from other agricultural

[*]PhD. Stud. Eng. *Ana* Zaica: zaica_ana@yahoo.com

plants involved in human nutrition, although some of them are used as feed. We can speak of a direct relationship agricultural plants - fodder plants - animal nutrition, [1-3].

Perennial legumes (such as alfalfa, clover, sparse, orchard) in the meadows have the most important role in producing a high-quality feed rich in protein, plus the extraordinary attribute of atmospheric nitrogen, living in symbiosis on the roots with a bacterium called Rhizobium sp. This miraculous process benefits organic farming, [4].

Leguminous plants represent an important group of plants that participate in the planting of the vegetation of the meadows, but in a smaller proportion than the grasses. Legumes are typically 5 to 10 percent of grassland vegetation and have a high economic value due to valuable chemical composition, high yields, and high digestibility. The degree of consumption is very high in most legumes, both green and hay, [5-7].

Clover due to the high content of nutrients is highly appreciated in the daily fodder of animals, especially dairy cows, and under optimum harvesting technology; high quality hay is produced. The nutritional value of the green clover is maximal in the early flowering phase, which corresponds to the optimal harvesting period. Clover thistle is also rich in protein and calcium and contains large amounts of carotene when it is preserved and preserved under some conditions. In animal feed it is used similarly to lucerne. [8].

The optimal harvesting period for clover and lucerne corresponds to the beginning of the flowering phase when the protein content is maximum and corresponds to a plant humidity of about 75 … 80% and the production per hectare is satisfying.

Obtaining valuable feeds, as well as composition, requires special attention to the exploitation of meadows through the use of harvesting and conservation methods and technologies with minimal losses and reduced costs. Climatic and landscape conditions also allow grass and leguminous fodder plants to be grown to conserve fodder throughout the year.

Harvesting and preparing, then preserving grass and fodder feed in the form of hay are the basic work to get a final product with a nutritional value closest to the original feed of the green feed. In order to complete the drying of the clover fodder in the warehouses, special ventilation systems with cold air or hot air are required, suitably sized according to the farm's feed requirements, [9].

2 Methodology

Preparing the clover hay using the ventilation method with cold air or hot air in the process of aeration drying by means of the ventilation system consists in removing water from the feed in a shorter time by using the air streams introduced by the fan. In this way, losses of nutrients and vitamins, as well as mechanical losses, are much lower and the harvested hay is green, pleasant aroma and a high content of vitamins.

The pilot plant (IVF) for finishing the drying of the hay is designed to reduce the humidity of fodder stored from humidity of 35 ... 40% at humidity of approx. 17% by ventilation with cold or heated air for optimal long-term conservation and obtaining of quality feeds in the final phase of feed drying technology, Figure 1. In order to heat the ventilation air, the installation uses solar radiation, which is heat converted with the aid of solar panels and transported via aluminium tubes [10].

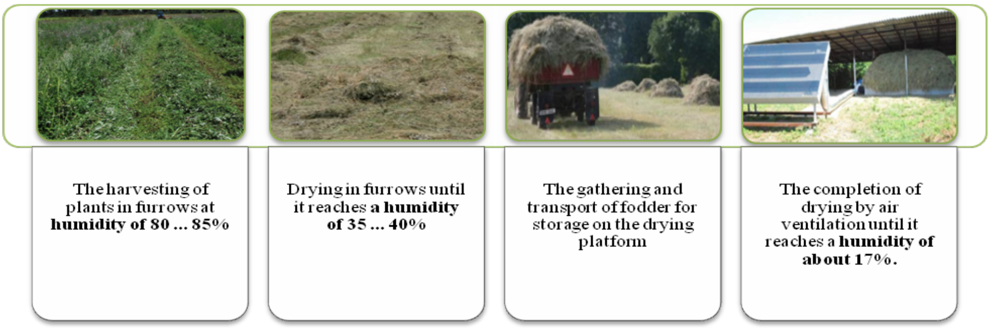

Fig. 1. Phases of feed drying technology by air ventilation.

For that, determinations and measurements were carried out following the variation of the main parameters:

- atmospheric air temperature and humidity, used as an aeration agent during the drying process of the feed;
- air temperature and humidity in the solar panel, part of the installation;
- the temperature and humidity in the feed mass (clover) deposited on the plant platform for drying for optimal storage;
- the duration of the drying process by ventilation.

In order to measure the humidity of the feed during the aeration process, samples from 4 different areas of the platform Figure 2 were collected to trace if the clover hay was uniformly dried.

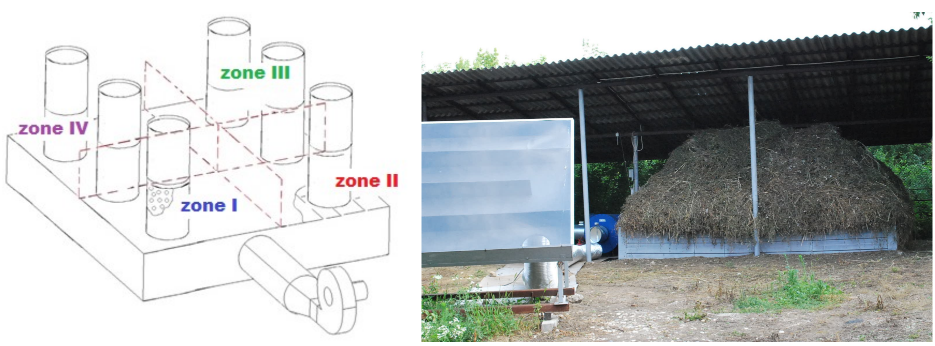

Fig. 2. Schematic diagram of the platform, component part of the installation, with division by areas and installation loaded during experimental research.

The test period is characterized by high summer atmospheric temperatures (July) and low air humidity, the material undergoing the aeration process is composed of clover fodder plants harvested from an experimental lot.

The clover drying operation deposited on the platform begins when the ventilation system is switched on and the fan suction air (cold or heated) is introduced through the intake channel into the uniformization chamber from where it is diffused into the mass of the layer of fodder stored. A layer of material with a height of at least 2 m is thick enough to prevent rapid flow of air through the plant mass.

The ventilation program adapts to weather conditions and storage parameters on the experimental plant platform.

In the technology of drying the heated air feed, it is necessary during the aeration process to continuously control the temperature in the feed mass. It must not rise above 30ºC. When hot air was used for ventilation drying, the drying process ends with cold air to ensure that the temperature of the feed mass is balanced with atmospheric air temperature, thus avoiding any condensation.

During experimental research on experimental research, to achieve the objectives are establish and determines the functional characteristics and working indices presented in Table 1.

Table 1. Determination of functional characteristics and working indices

No. crt.	**Specification**		**UM**	**The determined value**
1	Fodder type		-	White clover
2	The drying period		-	July
3	Humidity of fodder when loaded on the drier		%	45,38
4	The height of the fodder layer		m	2
5	Active dimensions of the drying platform	Total length	m	6
		Width	m	6
		Height	m	0,65
6	The total surface of the drying platform		m^2	36
7	The overall height of the hay		m	4,6
8	The initial fodder loaded on the platform (at loading humidity)		kg	3000
9	Number and brand of fans used		buc.	1 buc., tip HM 90 T4 5,5
10	Main Technical Features Fan HM 90 T4 5.5	The power	kW	5,5
		Supply voltage	V	380
		Maximum air flow	m^3/h	45000
		The pressure produced (according to the fan diagram)	mm H_2O	35 mm H2O at the flow rate of 25000 m^3/h 60 mm H2O at the flow rate of 10000 m^3/h
		Fan tube diameter on the platform	mm	900
11	Number of routing tubes for air in the hay		buc.	6
12	Dimensions of routing tubes for air	Diameter	mm	250
		The length	mm	2000
13	Type of the temperature probe in the feed mass		-	Thermal resistance PT100 with temperature control and control panel
14	Technical characteristics for thermo resistance	The maximum temperature	^oC	100
		Length of the stem	mm	950
	Data relating to the air heating system required for ventilation			
15	Type of installation and main technical features	Type	-	Solar panel
		Type of collectors	-	Solar planers mounted on the ground
		Mounting mode	-	Southern exhibition, mounted on the ground on a special stand beside the hay platform
		Horizontal angle	grade	45
		Total capture area	m^2	540
16	Type of connection to the air heating system and fan		-	Aluminium tube
17	Fan suction tube diameter		mm	400

Therefore, the quantitative and qualitative loss in hay harvesting and preservation is as small as possible, it is necessary to meet the following requirements to control the action of factors that influence the ventilation process proportionally:

- harvesting the plants in optimal phenophase;
- not to exceed the optimal harvesting age;
- shortening as much as possible the time elapsed from the beginning of the harvest to the hay at the optimal humidity (below 17 ... 18%);
- high - performance execution of agricultural works within the technology;
- execution of high quality works by observing imposed agro technical requirements (cutting height, reduced quantitative and qualitative losses for each operation, etc.);
- the use of equipment, machines and aggregates specific to working on sloping land and compliance with the conditions imposed in this case;
- introducing in hay harvesting and preservation technologies the mowing condition of crushing, breaking or defibration, works that shorten the drying time;
- reducing the shelf-life of mowed fodder by using modern dry-drying facilities.

3 Results

The results from the application of the ventilation experiment experimental methodology for experimentation will be presented in order to determine some of the parameters that influence the drying process.

During the experimental research period, the variation of air parameters, humidity and temperature, is presented as data in Table 2 and Table 3.

Table 2. Results of atmospheric air humidity measurements

Day	**U** [%] **air atm.**					**The average humidity, %**
	hour **7.30**	hour **9.30**	hour **11.30**	hour **13.30**	hour **15.30**	
1	88	83	65	52	61	69.8
2	92	86	68	71	59	75.2
3	75	71	52	58	55	62.2
4	82	64	51	37	33	53.4
5	85	58	47	32	38	52.0
6	78	74	60	44	71	65.4
7	64	64	45	37	34	48.8
8	85	75	69	69	59	71.4

During the studied period, the influence of the atmospheric conditions on the drying process is observed in the case of the material placed on the drying platform being the clover.

Knowing from the literature that clover is a leguminous plant, which contains more nutritive substance but has a rather high moisture content. During rainy periods, the drying process will be carried out only by ventilation with cold air for 30 minutes. at 2h. Ventilation is short-lasting so the feed does not absorb excess humidity in the air.

The data in Table 3 highlights high atmospheric temperatures throughout the day, characterized by a warm weather but with a rather high humidity during the morning.

Table 3. Results of atmospheric air temperature measurements

Day	T [°C] air atm.					The average temperature, °C
	hour **7.30**	hour **9.30**	hour **11.30**	hour **13.30**	hour **15.30**	
1	21	19	29	31	31	26.2
2	19	21	23	21	30	22.8
3	19	23	24	20	21	21.4
4	17	22	28	31	32	26.0
5	18	27	26	26	33	26.0
6	20	21	26	32	22	24.2
7	21	21	27	30	30	25.8
8	21	24	25	30	28	25.6

The results of the humidity and temperature measurements in the clover feed are shown in Table 4, and the data interpretation was performed by plotting the graphs in Figure 3 and Figure 4.

Table 4. The results of the humidity and temperature measurements of the clover fodder

Day	Mass moisture of clover-fodder samples [%]				Average humidity	Duration of the aeration process [h]	Temperature in the mass of clover-fodder[° C]				Average temperature
	zone I	zone II	zone III	zone IV			zone I	zone II	zone III	zone IV	
1	33.28	35.26	29.32	51.30	37	8	19	21	18	18	19
2	27.63	34.22	30.62	30.19	31	5	18	21	18	19	19
3	15.72	16.78	36.75	15.79	21	4	18	24	18	19	20
4	20.20	26.19	18.81	22.68	22	3	19	20	18	19	19
5	15.86	27.16	16.10	31.59	23	3	19	19	20	19	19
6	13.16	21.64	26.87	14.38	19	7	25	26	23	24	25
7	13.85	18.58	15.12	14.52	16	5	23	19	20	24	22
8	12.16	16.92	11.55	12.50	13	2	25	24	21	23	23

Graphical data mapping shows how the moisture content of the clover material stored for drying in the four areas set as a benchmark during tests varies, thereby determining the uniformity of dryness and shortening the duration of the process.

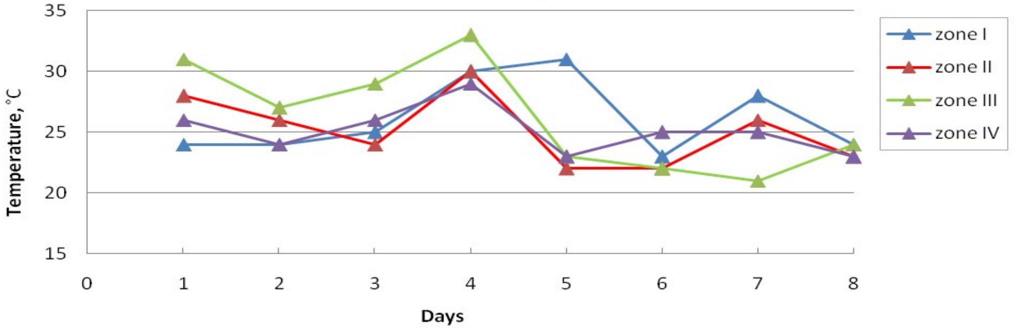

Fig. 3. The temperature variation in the mass of the clover-fodder during the aeration process in platform areas.

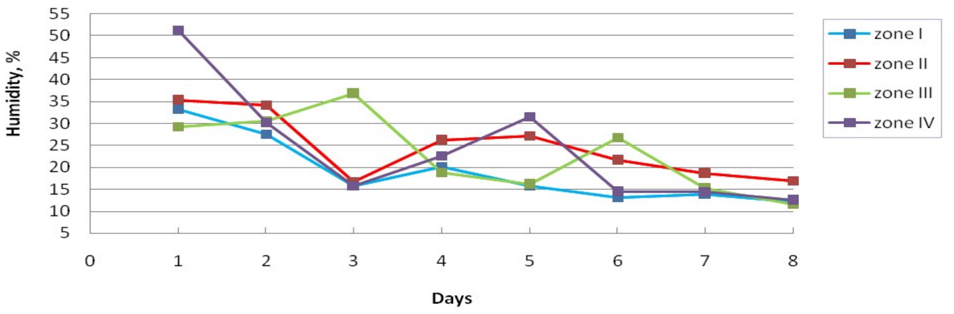

Fig. 4. Variation of the moisture content of the deposited material (clover) during the aeration process in different areas of the platform.

It can be noticed that the temperature variation recorded in the material reaches certain warning points on the material warming in zone 1 (Figure 3) on days 5 and 7, and in zone 3 during the first 4 days of ventilation, the temperature is kept at values that could affect the fodder quality. These high values, which exceed the average of 30ºC in feed, are reflected in keeping the initial moisture of the deposited material in zone 3 during the first days of the aeration drying process, even with the slight increase tendency from 30.62 to 36.75%.

Zone 1 (Figure 4) best performs the drying process by loss of feed moisture, instead the most spectacular decrease in humidity is recorded in platform 4 (Figure 4), about 40% loss of moisture during the same period, 8 days.

The comparative analysis of the results of the aeration process over the ventilation drying trial periods under experimental research is expressed in the values and observations in Table 5.

Table 5. Comparative analysis of the obtained results

Characteristics	**UM**	**Fodder**	**Observations**
Type	-	white clover	
Humidity at harvest	%	74,07	
Date of harvesting		july	
Drying time on the ground		Aprox 2 days	Successive turns of the furrow
Drying time	-	09.07: ora 14^{00} 22.07: ora 12^{00}	
Drying time on the feed platform	days	8	
Drying time of starch forage	hours	45	
The initial feed load loaded on the platform (at loading humidity)	kg	3000	
Storage humidity on the platform	%	45,38	Zone variations: 45,38…51,30
Moisture after ventilation	%	12,50…16,92	
Electricity consumption	kWh	199	
The amount of hay obtained when drying is complete	kg	1973	

4 Conclusions

Green fodder at harvest contains a large amount of water, generally between 70% and 85%. For winter storage, it should be subjected to aeration drying so that its moisture content is reduced to below 18%, so storage will be done in optimum conditions without the occurrence of undesirable phenomena (eg. molds).

Experimental research and prior studies can provide a number of advantages for using the aeration drying process in the appropriate installations as follows: it allows to obtain a high quality hay (with a high nutritive value, with a pleasant smell, close to the grass of origin) due to shortening the shelf life of the feed after mowing and reducing dependence on weather conditions during harvesting.

Compared to cold air drying and heated air drying, it has the following advantages:

- reduces dependence on atmospheric conditions during harvesting;
- shortens the drying time of feed;
- the initial moisture content of the dried fodder can be 10 to 15% higher, which leads to an even better hay quality.

By supplementary drying of the hay with mechanical ventilation systems, the loss of nutrients up to 25 ... 30% or even 50 ... 70% in adverse weather conditions is reduced.

Conditions for drying fodders differ from one species to another, depending on their subsequent destination. These conditions refer to the temperature of the drying agent, the humidity and the duration of the drying process.

Acknowledgement

This work was supported by a grant of the Romanian Research and Innovation Ministry, through Programme 1 – Development of the national research-development system, sub-programme 1.2 – Institutional performance – Projects for financing excellence in RDI, contract no. 16 PFE.

References

1. N. Dumitrescu, *Pajiști degradate de eroziune și ameliorarea lor*, (Ed. Ceres, Bucharest, 1979).
2. P. Mănişor, *Mecanizarea lucrărilor de producere a furajelor*, (Ed. Ceres, Bucharest, 1982).
3. http://www.scrigroup.com/tehnologie/merceologie/Factori-care-influenteaza-oper63115.php.
4. T. Maruşca, V. Blaj, M. Rusu, *Tehnologii de creştere a valorii pastorale pentru pajiştile montane*, Program ADER 2020, Project 1.3.3./2011, UMPP – ASAS, Bucureşti, (2012).
5. V. Mocanu, I. Hermenean, *Mecanizarea lucrărilor agricole pe pajişti - Tehnologii, maşini şi echipamente*, Ed. Univ. Transilvania, Braşov, (2013).
6. V. Neculăiasa, I. Dănilă, *Procese de lucru și mașini agricole de recoltat*, (Ed. A92, Iași, 1995).
7. A. Muimba-Kankolongo, *Chapter 10 - Leguminous Crops, Food Crop Production by Smallholder Farmers in Southern Africa Challenges and Opportunities for Improvement*, 173-203, (2018).
8. V. Mocanu, *Tehnologie modernizată pentru culturile specifice zonei Făgăraş în vederea instalării stării de agroclimax*, (Ed. Capo-Lavoro, Braşov, 2011).
9. A. Nedelcu, G. Lazar, R. Dragan, V. Ciobanu, ACTA, fas. 4, (2012).
10. A. Nedelcu, R. Ciuperca, L. Popa, E. Voicu, A. Zaica, INMATEH - Agri. Eng. **43**, 81-86 (2014).